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The T-100-12.8 Family of Cogeneration Steam Turbines: Yesterday, Today, and Tomorrow

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Abstract—The T-100-12.8 turbine and its versions, a type of cogeneration steam turbines that is among best known, unique, and most widely used ones in Russia and abroad, are considered. A list of turbine design versions and quantities in which they were produced, their technical and economic indicators, design features, schematic solutions used in different design versions, and a list of solutions available in a comprehensive portfolio offered for modernizing type T-100-12.8 turbines are presented. Information about amounts in which turbines of the last version are supplied currently and supposed to be supplied soon is given.

Keywords: steam turbine, district heating cogeneration, high-pressure cylinder, intermediate-pressure cylinder, low-pressure cylinder, steam admission, control stage

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Now, when preparations to the 75th anniversary of the Ural Turbine Works are underway, we would like to touch the topic about the T-100-12.8 (T-100) turbine and its design versions, which is one of the best known, unique and most widely used cogeneration steam turbines in Russia and abroad. The first T-100-12.8 turbine was put in operation in 1961 at Mosenergo's TETs-20 cogeneration station (CSs). Turbines of the T-100 series, which were intended for use at newly constructed and expanded CSs in large and medium-size cities, were designed with a certain degree of versatility; i.e., they had fairly good efficiency both during operation at different heat loads and in purely condensing modes. The turbine has a well-developed low-potential part, a condenser group with the optimal flowrate of cooling water, and a well-developed regeneration system, due to which it became very popular. Since 1961, the Ural Turbine Works (formerly TMZ) has produced 245 turbines of the T-100 family, which were issued in different design versions in different years and commissioned at 106 CSs and district power stations (DPSs) in 13 countries around the world.

Turbines of the T-100 family have always featured high efficiency and reliability indicators and, accordingly, met almost all requirements of their customers.

The T-100 turbine is a single-shaft set consisting of high-, intermediate-, and low-pressure cylinders (HPC, IPS, and LPC) and fitted with a nozzle-type steam admission system. Live steam is supplied via steam lines to the stop valve, from which it is fed through four crossover pipes to four boxes of control valves. Control valves are manipulated by means of a cam-type distribution device, the shaft of which is driven by a servomotor through a toothed bar.

Steam passes through the HPC in a direction opposite to that in the IPC, due to which the HPC blade system is designed for leftward direction of rotation. The HPC flow path, which has a yokeless design, includes a two-row control stage and eight impulse-type stages. The first regenerative extraction of steam in the HPC is taken from its exhaust. This solution, according to which there are no steam extractions from the cylinder itself, simplifies the HPC design. Steam leaving the HPC is forwarded to the IPC via four crossover pipes.

The turbine unit does not have a steam reheat system because the gain in efficiency obtained from using steam reheating in turbines having heating or process steam extractions is smaller than in condensing turbines; nonetheless, a few draft design versions of the turbine with steam reheating have been elaborated [1, 2].

The intermediate-pressure cylinder consists of a cast-and-welded steam admission part and a welded exhaust part interconnected by a vertical flange. The cylinder comprises eight stages with all-forged disks and six subsequent stages with shrunk-on disks.

The low-pressure cylinder has a double-flow design and consists of a middle part and two exhaust parts connected to the middle part on both sides. Each of two LPC flows has two stages. Control diaphragms are installed at the flow path inlet, which serve to perform control within the required pressure range in the chamber of lower district heating extraction in the case of using single-stage heating of delivery water, as well as in the chamber of the upper district heating extraction in the case of using two-stage heating of delivery water. The diaphragms are driven by a servomotor.

In different years, changes were introduced in the turbine design in order to improve its reliability, repairability, as well as its performance and technical-economic indicators, and its design version was changed when the new turbine became considerably different from its previous version. Table 1 lists the issued versions of the T-100 turbine and the quantities in which they were produced.

The design of the T-110/120-12.8-4 turbine underwent the most significant changes, all of which were reflected in the new version T-110/120-12.8-5, which was put in operation at the Biisk TETs-1 cogeneration station in 1984. For example, in order to achieve more reliable operation of this turbine, axial-radial seals began to be used in the HPC and in the 10th to 16th stages of the IPC [3]. In order to reduce stresses in the most dangerous zone by almost a factor of 2, to exclude the possibility of corrosion deposits to fall on the disk boring surface, and to avoid the danger of cracks to appear on this surface, shrunk-on disks with end-face keys without a longitudinal key slot were used in this turbine. In addition, the shrunk-on disks for this turbine began to the made of Grade 35KhN1M2 steel having better resistance to corrosion cracking instead of Grade 34Kh1M and 34KhN3M steels.

Based on the experience gained from operation of 550-mm-long last-stage blades in a steamless mode, the design of tight LPC control diaphragms began to be applied in this version, the use of which minimizes leaks of steam into the condenser and heat losses with cooling water, with the result that up to 2140 tce of fuel can be saved per annum [4].

The project of the T-110/120-12.8-5 turbine incorporated a lot of improvements, due to which it became significantly more superior to the turbines of previous design versions. The main design features and technical-economic indicators of turbines of the T-100 family are summarized in Table 2.

The T-110/120-12.8-5 turbine can be installed on the pedestal of turbines of all previous versions, due to which it became possible to carry out quite a number of partial and full-scope replacements of turbines installed at Mosenergo's cogeneration stations. The availability factor of a turbine unit equipped with this turbine reaches 0.99.

In 2008, specialists of the Ural Turbine Works developed a comprehensive portfolio for modernizing turbines of the T-100 family [5], which comprises the following: a new HPC with a single-row control stage intended for a live steam flowrate of 520–525 t/h; intermediate, end, and overshroud cellular seals for the HPC; an intermediate-pressure rotor with modernized stages and solid half-couplings; steel welded intermediate-pressure diaphragms, a modernized cam-type distribution device with a reinforced frame; modernized control and stop valves; a support-and-thrust bushing with modernized thrust pads having increased bearing capacity; and a new microprocessor electrohydraulic control and protection system (EHCPS). This portfolio is widely used in renovation of turbines. After carrying out such renovation, technical specifications are issued with a new assigned equipment service life equal to 40 years and with the service life of parts and components operating at a temperature of higher than 450°C equal to 220 000 h.

Table 1. The list and number of all produced versions of turbines of the T-100 family

Designation	Quantity	Production commencement year
T-100-12.8	58	1961
T-100/120-12.8-2	29	1971
T-100/120-12.8-3	59	1974
T-110/120-12.8-4	47	1979
T-110/120-12.8-5	40	1984
T-116/120-12.8-7	7	1990
T-118/125-12.8-8	2	2005
T-120/130-12.8-8MO	3	2008

All solutions available in this modernization portfolio were used in working out a new design version of the turbine denoted by T-120/130-12.8-8MO (see the figure), which is presently offered to the customers.

The HPC flow path of the T-120/130-12.8-8MO turbine consists of a single-row control stage with a mean diameter of 1100 mm and 10 pressure stages with rotor blades the root diameter of which is equal to 800 mm. Owing to the use of a single-row control stage instead of a two-row-one in combination with the use of blades having aerodynamically more advanced profiles in the pressure stages, the HPC efficiency has been increased by approximately 3.5%. Cellular seals were applied as shroud, diaphragm, and end ones, the use of which increases the HPC efficiency by another 1.0–1.2%.

The IPC has a more aerodynamically advanced steam admission part. The first eight stages (from 11th to 18th) are fitted with cellular diaphragm seals. The IPC end seals are also of a cellular type. In view of increased steam flowrate to the HPC, the outlet areas of the 11th to 13th stages have been increased. The

Table 2. Characteristics and technical-economic indicators of turbines of the T-100 family

Indicator	Turbine design version			
	T-100-12.8	T-100/120-12.8-3	T-110/120-12.8-5	T-120/130-12.8-8MO
Capacity, MW:				
nominal	100	110	110	123
maximal	120	120	120	130 (up to 136)
maximal in the condensing mode	100	110	120	130 (up to 136)
Live steam flowrate, t/h:				
nominal	441	480	480	520
maximal	460	485	485	525
maximal in the condensing mode	368	398	432	465
Rated heat load, GJ/h	670	733	733	787
Steam rate, kg/(kW h):				
in the cogeneration mode	4.41	4.30	4.27	4.23
in the condensing mode	3.68	3.62	3.60	3.60
Heat rate in the condensing mode, kJ/(kW h) [kcal/(kW h)]	9239 [2210]	9158 [2191]	9016 [2154]	8955 [2139]
Feedwater temperature in the nominal mode of operation, °C:	229	232	234	236
Average internal efficiency of the flow path, η_i	74.2	78.6	81.3	87.9
Control stage (CS)	Two-row CS	Two-row CS	Two-row CS	Single-row SC
Modernization of a high-pressure cylinder				
Increase of the HPC throughput capacity:				
replacement of the guide vane	–	+	–	+
replacement of the high-pressure stator blade system	–	+	–	+
replacement of the high-pressure rotor blade system	–	+	+	+
Installation of a current pickup device	–	–	+	+
A new cam-type distribution device (CDD) with installing a stiffer frame and bearings with increased bearing capacity. Installing a sector with two eyes on the CDD for increasing the sector service life	–	–	+	+
Modernizing the HPC seals (front, bearing, and overshroud):				
radial by axial-radial	–	–	+	
axial-radial by cellular	–	–	–	+
radial by axial-radial in the control stage	–	–	+	+
Modernizing the flange and stud heating system for improving the maneuverability. The old ducts are dismantled. Heating is performed by supplying steam into the deepened wrapping of the HPC horizontal joint	–	–	+	+
Installing a new HPC for the flow path with a single-row control stage	–	–	–	+
New control valves. Installation of perforated crown knot and seat for improving aerodynamics and reducing hydraulic losses, and modernization of the stem hanging assembly	–	–	+	+
Single-row high-pressure rotor	–	–	–	+

Table 2. (Contd.)

Indicator	Turbine design version			
	T-100-12.8	T-100/120-12.8-3	T-110/120-12.8-5	T-120/130-12.8-8MO
Installation of new intra-turbine pipelines for a single-row HPC, HPC crossover pipes, and pipeline of drains, suction from valve stems, flange and stud heating pipelines, and governing oil line	–	–	–	+
Load lifting devices for the high-pressure rotor and HPC (a single-row HPC)	–	–	–	+
Organizing additional steam extraction with a flowrate of 70 t/h and pressure of 1.0–1.3 MPa with installing the unit of combined protection and control valve	–	–	+	+
Modernization of the front bearing unit				
Replacing an obsolete turbine control system by a new automatic closed-loop control system built using modern components and control algorithms, including parts required for retrofitting the existing actuators of an electrohydraulic control system	–	–	+	+
Modernization of the turbine expansion system by installing sliding surfaces with a smaller friction coefficient	–	–	+	+
Support-and-thrust bearing				
Installation of laminated pads with increased bearing capacity	–	–	+	+
Installation of a new bearing with tangential oil removal	–	–	+	+
Modernization of an intermediate-pressure cylinder				
Welded IPC (with a cast design of the steam admission system up to the 11th stage and then a welded design)	–	–	–	+
Replacement of the 10th stage guide vane	–	–	+	+
Replacement of the diaphragms in the 11th and 12th stages	–	–	+	+
Installation of welded diaphragms for the 11th to 23rd stages to avoid washout of the guide vanes	–	–	+	+
Strengthening of the 15th, 20th, and 22nd stages (new disks and reinforced blades)	–	–	+	+
Replacing the rotor blades of the 10th to 12th stages	–	–	+	+
A new high-pressure rotor (newly designed disks of the 18th to 23rd stages for ensuring the reliability of sealing rings)	–	–	–	+
Replacement of labyrinth end and diaphragm seals by axial-radial ones	–	–	+	
Replacement of axial-radial end and diaphragm seals by cellular ones	–	–	–	+
Replacement of overshroud labyrinth seals by axial-radial ones for the 10th to 14th stages	–	–	+	
Replacement of overshroud axial-radial seals by cellular ones for the 10th to 14th stages	–	–	–	+
Modernizing the IPC drain and compartments ventilation systems to exclude filling the drains with steam and to achieve deeper drying of the flow path	–	–	+	+

Table 2. (Contd.)

Indicator	Turbine design version			
	T-100-12.8	T-100/120-12.8-3	T-110/120-12.8-5	T-120/130-12.8-8MO
Modern turbine monitoring facilities				
Fitting a turbine with modern facilities for monitoring linear and angular displacements and vibration state of turbine elements with producing warning and emergency alarms	–	–	+	+
Retrofitting of low-pressure cylinders				
Modernizing the IPC-to-LPC crossover pipes for removing cycle moisture from the steam flow	–	–	+	+
Modernizing the moisture removal system by improving the design of yokes	–	–	+	+
Modernization of the low-pressure rotor with making a shift for using end-face keys and solid half-couplings for ensuring reliability and repairability. A shift for using solid half-couplings is made only provided that a new high-pressure rotor is installed	–	–	+	+
Leaktight LPC diaphragms	–	–	+	+
Stop valve				
Retrofitting aimed at excluding the possibility of the stem to suspend	–	–	+	+

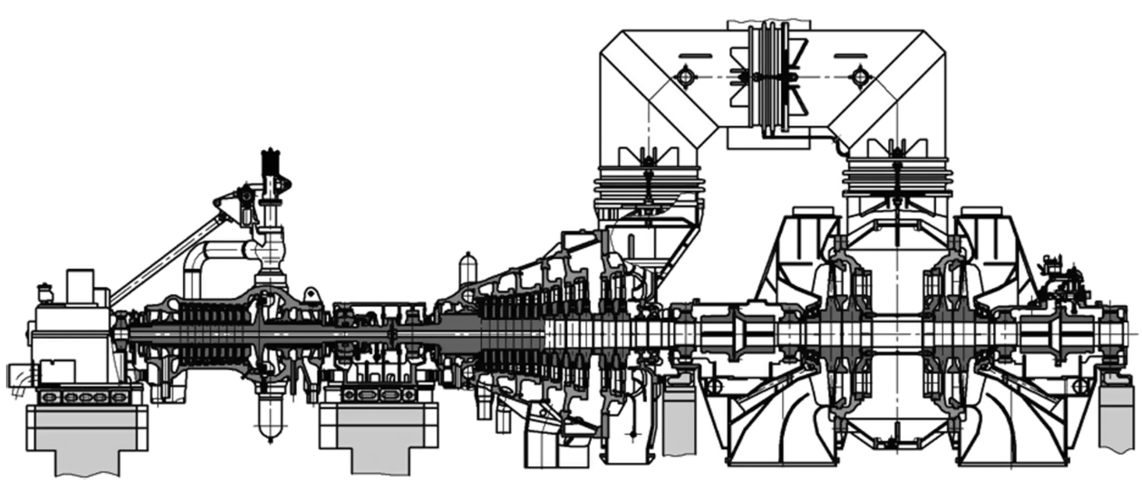
15th, 20th, and 22nd stages of the turbine have rotor blades with a new profile, due to which more reliable performance of the blade system is achieved.

The LPC last-stage blades have a height of 550 mm. The performance of this stage has been proven in the course of long-term use in a large fleet of turbines operating with variable pressure in the condenser and with a wide variation range of volume steam flowrate. The LPC is made with cellular end seals. The IPC-LPC receiver contains hollow rotary blades for removing moisture from the flow core.

For meeting the needs of cogeneration station consumers in process steam, the turbine design incorporates the possibility of extracting up to 70 h/t of steam from the HPC-IPC receiver.

The turbine is equipped with an electrohydraulic control and protection system.

Type T-120/130-12.8-8MO turbines were supplied to the Astana (Kazakhstan) and Abakan CSs. In 2013, a turbine for the Kirov TETs-4 cogeneration station will be shipped, and in 2014, turbines for the Ulan-



The T-120/130-12.8-8MO turbine.

Bator TETs-4 (Mongolia) and Astana cogeneration stations will be shipped.

In 2015, an entirely new turbine of this family denoted by T-125/150-12.8 (which is being designed) will be offered to the customers. This turbine will be made with the use of advanced solutions and will have improved technical and economic indicators, due to which this turbine can compete with all word-level analogs in this class of capacities.

REFERENCES

1. G. D. Barinberg and A. E. Valamin, "Type T-130/130-12.8 Cogeneration Steam Turbines with Reheating," Therm. Eng., No. 8, 637 (2008).
2. G. D. Barinberg, A. E. Valamin, Yu. A. Sakhnin, and A. Yu. Kultyshev, "The T-120/130-12.8 and PT-100/130-12.8/1.0 cogeneration steam turbines produced by the Ural Turbine Works for replacing turbines of the T-100 family," Therm. Eng., No. 1, 8 (2011).
3. G. D. Barinberg, "Axial-radial shroud seals and their effectiveness," Sbornik TsNIITEItyazhmash, Issue 1, 40–43 (1988).
4. G. D. Barinberg, "Thermal efficiency of the T-100/120-130 turbine during its operation according to a heat generation schedule with and without passage of steam to the low-pressure cylinder," Elektr. Stn., No. 4, 43–47 (1990).
5. A. E. Valamin, Yu. A. Sakhnin, V. B. Novoselov, and A. A. Ivanovskii, "Retrofitting of T-100/110-12.8 Cogeneration Steam Turbines," Therm. Eng., No. 9, 747 (2009).

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